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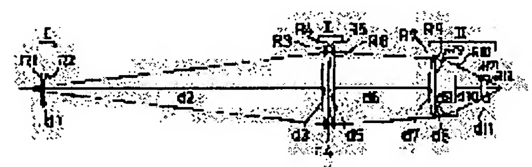
(54) REDUCTION STEPPING LENS

(57)Abstract:
PURPOSE: To provide the reduction stepping lens which is improved in transmittance and is provided with high resolution by reducing the total thickness of the glass material of a lens system.
CONSTITUTION: This reduction stepping lens is composed of total three groups; a first group I having a negative refracting power, a second group II having a positive refracting power and a third group III having a positive refracting power and is constituted to satisfy the conditions 3<|f1/f|<5, 10<f2/f<25 when the focal lengths of the first group I, the second group II and the entire system are respectively defined as f1 f2 and f. The respective groups have at least one face of aspherical faces. The respective aspherical faces are preferably aspherical faces of a shape to weaken the refracting power near the optical axis nearer the peripheral edges from the optical axis of the lenses. The respective lenses are preferably composed of the glass material having a refractive index of 3 ≤1.6.



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CLAIMS

[Claim(s)]
[Claim 1] A contraction projection lens characterized by satisfying the following conditions when it consists of a total of three groups of the 1st lens group with negative refractive power, the 2nd lens group with positive refractive power, and the 3rd lens group with positive refractive power in order and the 1st lens group, the 2nd lens group, and a focal distance of the whole system are set to f1, f2, and f from a body side, respectively.
$3<|f1/f|<5$ ... (1)
$10<f2 / f< 25$ ... (2)
[Claim 2] It is the contraction projection lens according to claim 1 which has the page [1st / at least] aspheric surface in each group, and is characterized by each aspheric surface being the aspheric surface of a configuration which weakens refractive power near the optical axis as it goes to a periphery from a lens optical axis.
[Claim 3] A contraction projection lens according to claim 1 characterized by constituting each lens by with a refractive index of 1.6 or less ** material.

[Translation done.]

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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] This invention relates to the contraction projection lens used in case the circuit pattern is imprinted on a silicon wafer about the contraction projection lens carried in the equipment which manufactures integrated circuits, such as IC and LSI, from the mask on which the circuit pattern was especially drawn by the reduced-projection-exposure method.
[0002]
[Description of the Prior Art] Generally, the resolution of a projection image with a projection lens is proportional to the numerical aperture, and in inverse proportion to the wavelength to be used. Although resolution will become good and it will go in proportion to it if high integration of a circuit pattern progresses, the good lens of resolution is required in connection with it, numerical aperture is enlarged and it goes in recent years, the depth of focus will need to become shallow and it will be necessary to perform focusing very correctly. A value also with the very severe display flatness of the silicon wafer which imprints a circuit pattern is required, and it will stop moreover, being fit for practical use. Therefore, raising resolution came to be performed in recent years, having shortened operating wavelength and maintaining the depth of focus rather than it enlarges numerical aperture.
[0003] In current, although 436 to 365nm light is used, there is a proposal of JP,60-140310,A which uses the KrF excimer laser which uses 248nm as an emission spectrum, JP,1-315709,A which uses the ArF excimer laser which uses 193nm as an emission spectrum in recent years. [by the mercury-vapor lamp]
[0004]
[Problem(s) to be Solved by the Invention] By the way, when the operating wavelength of projection exposure is set to 250nm or less, the viewpoint that there is little decline in the permeability of the ** material which can be used to ** material is SiO_2. Or CaF_2 It is restricted. And it is SiO_2 when processability etc. is taken into consideration. There is nothing and the ** material which can carry out deer use is this SiO_2 at the wavelength of 200nm or less further. Permeability is low even if it uses it. The conventional excimer laser is made into the light source, and it is SiO_2. Since there was much lens number of sheets and ****** thickness was thick, the used contraction projection lens had low permeability, therefore had problems, such as a low throughput by the scale-factor fluctuation by exposure light-and-heat absorption of a lens, best focus fluctuation, and the lack of light exposure.
[0005] This invention is made in view of such a condition, and the purpose is offering the contraction projection lens of high resolving which can make ****** thickness of a lens system thin and can raise permeability.
[0006]
[Means for Solving the Problem] In order to attain the above-mentioned purpose, a contraction projection lens of this invention The 1st lens group which has negative refractive power in order [side / body], and the 2nd lens group with positive refractive power, When it consists of a total of three groups with the 3rd lens group with positive refractive power and the 1st lens group, the 2nd lens group, and a focal distance of the whole system are set to f1, f2, and f, respectively, it is characterized by satisfying the following conditions.
[0007]
$3<|f1/f|<5$ ... (1)
$10<f2 / f< 25$ ... (2)
In this case, it has the page [1st / at least] aspheric surface in each group, and it is desirable [the aspheric surface] that it is the aspheric surface of a configuration which weakens refractive power near the optical axis as each aspheric surface goes to a periphery from a lens optical axis. Moreover, it is desirable to constitute each lens by with a refractive index of 1.6 or less ** material.

[0008]
[Function] Hereafter, the reason for having taken the above-mentioned configuration and its operation are explained to details. In order to secure high resolution and a large exposure field as a contraction projection lens, a curvature of field must be amended nearly completely. the lens which has positive and negative refractive power for that purpose although what is necessary is just to stop the PETTSU bar sum small in order to amend a curvature of field -- many -- to arrange in several sheets and a suitable location is required. Therefore, lens number of sheets of a contraction projection lens cannot but increase.
[0009] On the other hand, in order to make the permeability of a contraction projection lens high, ****** thickness must be made thin, but it is required to reduce lens number of sheets at the same time it makes one one-sheet lens thin for that purpose. That is, it is difficult to be satisfied with coincidence of the conditions of making thin the conditions of securing high resolution, and ****** thickness.
[0010] In order that the contraction projection lens of this invention may make the PETTSU bar sum small effectively by small lens number of sheets By the negative refractive power of the 1st lens group arranged to the body side in the location where the light high is low soon The negative large PETTSU bar value was generated and the configuration which makes the positive PETTSU bar sum small by the positive refractive power of the 2nd lens group arranged in the location where the light high by the side of the image surface after this is high, and the 3rd lens group is taken. By taking this configuration, it becomes possible to make the PETTSU bar sum small by small lens number of sheets.
[0011] | The conditional expression about f1 / f|, and f2 / f is the requirements for a configuration required in order to restrict the refractive power of each lens group and to attain the projection lens of high resolving. In this case, the refractive power of the 1st lens group becomes it small that |f1 / f| is five or more too much, the whole PATTSU bar sum cannot be stopped small, and when negative refractive power becomes it large that it is three or less, the curvature of the field of the 1st lens group becomes tight, and generating of many aberration becomes large. Moreover, image formation of the light cannot be carried out to f2 / f being 25 or more with the lens of the positive refractive power of small number of sheets, and when positive refractive power becomes it large that it is ten or less, generating of negative spherical aberration becomes large.
[0012] Furthermore, it is dS about the distance of f3F [set a before / the 3rd lens group / side focal location to f3F, and] on the basis of the backside [the 2nd lens group] principal point. When it carries out, it is desirable to satisfy the following conditions.
[0013]
- 0.1<DS/F2 <0.2 ... (3)
The sign of a formula (3) considers the time of being in a plus and body side about the time of f3F being in an image surface side rather than the backside [the 2nd lens group] principal point as minus. In a contraction projection lens like this invention, in order to suppress scale-factor fluctuation of the image by the badness of defocusing of the image surface or the surface smoothness of the image surface, it is common that it is a injection side tele cent rucksack. In the case of this invention, f3F are in agreement with a pupil location. That is, the above-mentioned conditions specify the relation between the 2nd lens group and a pupil location. - 0.1> dS / f2 If it becomes, inner comatic aberration will arise by the 2nd lens group, it will multiply by the inner comatic aberration produced by the 1st lens group, and comatic-aberration amendment by the 3rd lens group will be made difficult. On the other hand, in dS/f2 >0.2, although it has the operation which makes outside comatic aberration while amending spherical aberration as outside comatic aberration occurs too much strongly and mentions the aspheric surface of the 3rd lens group later, beyond the inner comatic aberration which the 1st lens group generates, comatic aberration will increase outside the 2nd and 3rd lens group, and outside comatic aberration will remain as a whole.
[0014] Moreover, as for the contraction projection lens of this configuration, it is desirable independently to have the page [1st / at least] aspheric surface in each group. This is for amending many aberration which cannot be amended with the above-mentioned configuration of small lens number of sheets. The aspheric surface of the 1st lens group is used in order to amend the positive distortion aberration generated here. The aspheric surface of the 2nd lens group is used in order to amend the negative spherical aberration by there being few configuration lens elements. The aspheric surface of the 3rd lens group is used in order to amend the spherical aberration generated for this lens group itself in order to amend the inner comatic aberration generated by the 1st lens group. Furthermore, it is desirable that it is the aspheric surface of the configuration which weakens the refractive power near the optical axis as these aspheric surfaces go to a periphery from a lens optical axis.
[0015] Moreover, as for the contraction projection lens of this configuration, it is desirable independently to constitute from with a refractive index of 1.6 or less ** material. In using light with very narrow spectral band width like excimer laser, this is because it is not necessary to take the chromatic aberration of a lens into consideration and a refractive

index does not need to use 1.6 or more ** material for chromatic-aberration amendment.
[0016]
[Example] Hereafter, the examples 1-4 of the contraction projection lens of this invention are explained. although the lens cross section of examples 1-4 is shown in drawing 1 - drawing 4 , respectively -- which example -- also setting -- a scale factor -- 1/5 and numerical aperture -- 0.45 and length between object images -- 1000mm and an exposure field -- 10x10mm -- it is -- ** material -- all -- SiO2 from -- it becomes. In addition, the postscript of the lens data of these examples is carried out.
[0017] First, the example 1 of this invention is explained. One negative meniscus lens by which the 1st group I turned the convex to the body side in drawing 1 to the 2nd group II is a total of two sheets, one biconvex lens and one positive meniscus lens which turned the convex to the body side, to the 3rd group III. It consists of a total of three sheets of two positive meniscus lenses which turned the concave surface to the image side, and one meniscus lens of power loess which turned the concave surface to the image side.
[0018] This example 1 and especially the example 2 described below are the 3rd group III. Although one meniscus lens of power loess which turned the concave surface to the image side at the place nearest to the image surface is arranged, in order to amend high order comatic aberration in this case, it is still more desirable to use the aspheric surface for oneth of them at least. Furthermore, when the focal distance of the meniscus lens of this power loess is set to f33, it is desirable to satisfy the following conditions.
2000 (mm) <|f33| ... (4)
| The comatic aberration of the low degree in a spherical-surface component will occur that f33| is 2000mm or less.
[0019] Next, the example 2 of this invention is explained. One negative meniscus lens by which the 1st group I turned the convex to the body side in drawing 2 to the 2nd group II is one positive meniscus lens which turned the convex to the body side to the 3rd group III. It consists of a total of three sheets, one biconvex lens, one positive meniscus lens which turned the concave surface to the image side, and one meniscus lens of power loess which turned the concave surface to the image side. The 3rd group III About the meniscus lens of power loess which turned the concave surface to the image side, it has the same operation as an example 1.
[0020] Next, one negative meniscus lens by which the 1st group I turned the convex to the body side in drawing 3 about the example 3 of this invention to the 2nd group II is one positive meniscus lens which turned the convex to the body side to the 3rd group III. It consists of one biconvex lens and one positive meniscus lens which turned the concave surface to the image side.
[0021] One negative meniscus lens by which the 1st group I turned the convex to the body side in drawing 4 about the example 4 of this invention to the 2nd group II is one positive meniscus lens which turned the convex to the body side the 3rd group III. It consists of one biconvex lens and one positive meniscus lens which turned the concave surface to the image side.
[0022] Although the lens data of each example is shown below, R1, R2, and ... are [the gap between each lens side, n1, n2, and ... of the radius of curvature of each lens side, d1, and d2 ...] 193nm in refractive index of each lens among lens data, and an aspheric surface configuration is expressed with a degree type when the direction which intersects the direction of an optical axis perpendicularly with x and an optical axis is set to y.
x=(y2 / r)/Paraxial radius of curvature, and A, B, C and D of 1+{1-(y2 / r2)} 1/[2]+Ay4+By6+Cy8+Dy10, however r the 4th aspheric surface coefficients [6th / 8th / 10th], respectively.
[0023] Example 1 R1 = 149.072 d1 = 4 n1 =1.56 R2 = 53.071 (aspheric surface) d2 = 580.412 R3 = 685.808 d3 = 12.808 n2 =1.56 R4 = -855.88 d4 = 0.08 R5 = 332.732 d5 = 10.304 n3 =1.56 R6 = 970.134 (aspheric surface) d6 = 196.429 R7 = 236.31 d7 = 10.938 n4 =1.56 R8 = 1175.523 d8 = 0.714R9 = 87.26 d9 = 42.891 n5 =1.56 R10= 194.005 d10= 53.429 R11= 68.841 (aspheric surface) d11= 13.136 n6 =1.56 R12= 2nd page [of a 59.862 aspheric-surface coefficient] A=-0.105x10-5 B -- =-0.126x10-9C=-0.242x10-13 D -- =-0.176x10-16 6th page A= 0.986x10-8 B= 0.485x10-13 -- = 0.44 x10-22 11th page A=-0.745x10-6 C= 0.116x10 to 17 D B=-0.359x10-9C=-0.115x10-12 D=-0.595x10-17 .
[0024] Example 2 R1 = 1736.215 d1 = 5.866 n1 =1.56 R2 = 68.889 (aspheric surface) d2 = 543.701 R3 = 263.312 d3 = 11.509 n2 =1.56 R4 = 819.653 (aspheric surface) d4 = 165.728 R5 = 220.315 d5 = 22.409 n3 =1.56 R6 =-1415.823 d6 = 49.904R7 = 106.825 d7 = 37.488 n4 =1.56 R8 = 254.313 d8 = 46.233R9 = 96.597 (aspheric surface) d9 = 6.904 n5 =1.56 R10= 103.38 2nd page [of an aspheric surface coefficient] A=-0.639x10-6 B=-0.155x10-10C=-0.103x10-13 D= 0.563x10-18 4th page A= 0.223x10-7 B= 0.151x10-12 -- C= 0.241x10-17 D= 0.209x10-21 9th page A= -0.277x10-6 B=-0.522x10-10C= -0.497x10-14 D= 0.69x10-18 .
[0025] Example 3 R1 = 6336.701 d1 = 4 n1 =1.56 R2 = 65.016 (aspheric surface) d2 = 561.539 R3 = 261.005 d3 = 15.817 n2 =1.56 R4 = infinity (aspheric surface) d4 = 176.959 R5 = 232.483 d5 = 20.768 n3 =1.56 R6 = -632.184 d6 =

40.867 R7 = 126.144 d7 = 28.872 n4 =1.56 R8 = 413.522 (aspheric surface) the aspheric surface coefficient 2nd -- page A=-0.779x10-6 B=-0.179x10-10C= -0.182x10-13 D= 0.307x10-17 page [4th] A= 0.268x10-7B= 0.792x10-13C= 0.250x10-17 -- D= 0.155x10-21 -- the 8th page -- A= 0.438x10-7 B= 0.215x10-12 -- C= 0.424x10-16 -- D= 0.645x10-20.

[0026] Example 4 R1 = 7761.76 d1 = 4 n1 =1.56 R2 = 65.426 (aspheric surface) d2 = 566.358 R3 = 260.181 d3 = 14.689 n2 =1.56 R4 = 3358.89 (aspheric surface) d4 = 167.605 R5 = 217.213 d5 = 21.986 n3 =1.56 R6 = -768.035 (aspheric surface) d6 = 44.28 R7 = 137.413 d7 = 26.994 n4 =1.56 R8 = 634.5 (aspheric surface) aspheric surface coefficient 2nd page A= -0.777x10-6 B -- =-0.144x10-10C=-0.182x10-13 D= 0.307x10-17 4th page A= 0.275x10-7 B= 0.13 x10-12C= 0.417x10-17 D= 0.175x10-21 6th page A= 0.523x10-9 B=-0.25 x10-12C= 0.951x10-17 D= -0.425x10-22 -- the 8th page -- A= 0.484x10-7 B= 0.678x10-12 -- C= 0.114x10-16 D= 0.534x10-20 .

[0027] Next, aberration drawing showing the spherical aberration of the above-mentioned examples 1-4, astigmatism, distortion aberration, and transverse aberration is shown in drawing 5 - drawing 8 , respectively. Among drawing, in Y, an image quantity ratio and M show the meridional image surface, and S shows the sagittal image surface. Moreover, the value of conditional-expression [of each example] (1) - (3) is shown in degree table.

	$\lvert f_1 / f \rvert$	f_2 / f	d_3 / f_2
実施例1	4.48	11.63	+0.15
実施例2	4.1	21.99	+0.14
実施例3	3.95	15.64	−0.04
実施例4	4.01	17.09	−0.05

[0028]

[Effect of the Invention] As explained above, according to this invention, the ****** thickness of a lens system is thin and the contraction projection lens of high resolving with sufficient permeability can be obtained.

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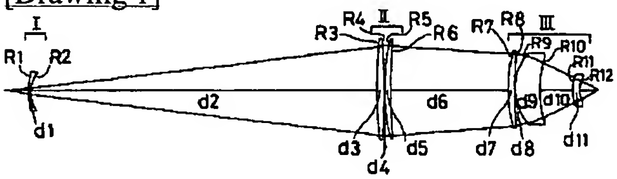
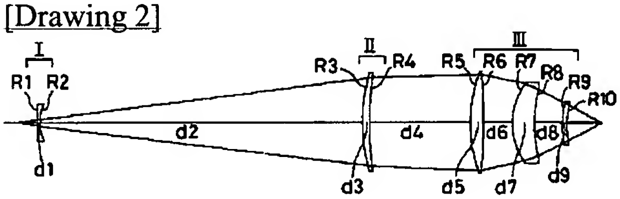
DRAWINGS

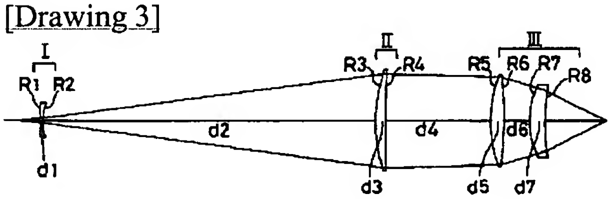
[Drawing 1]



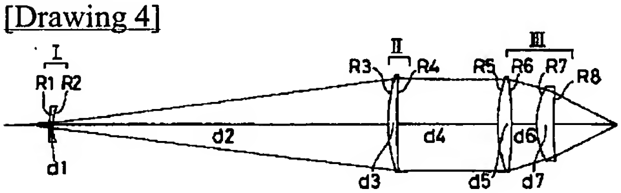
[Drawing 2]



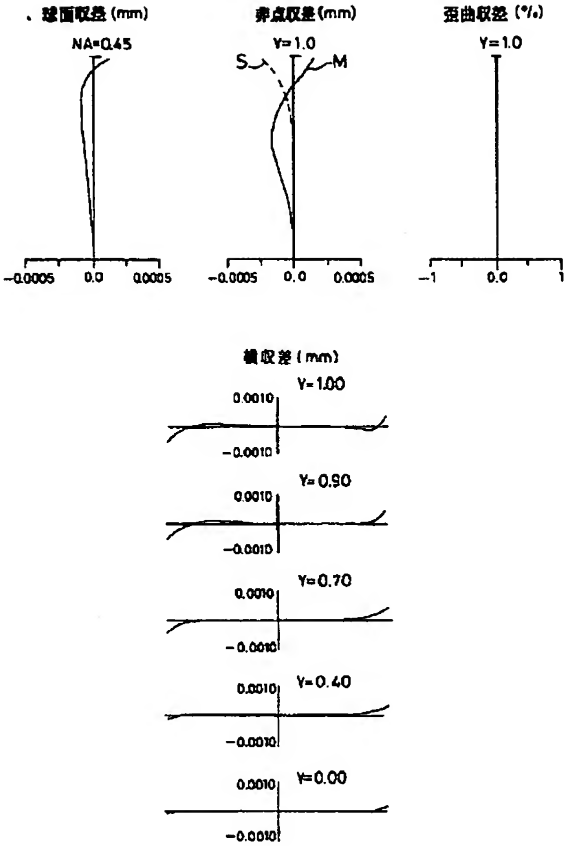
[Drawing 3]



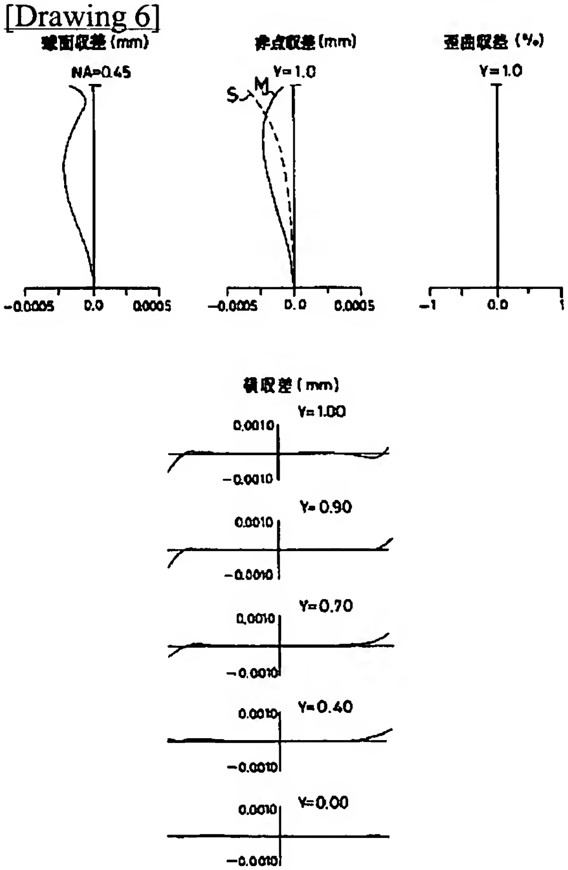
[Drawing 4]



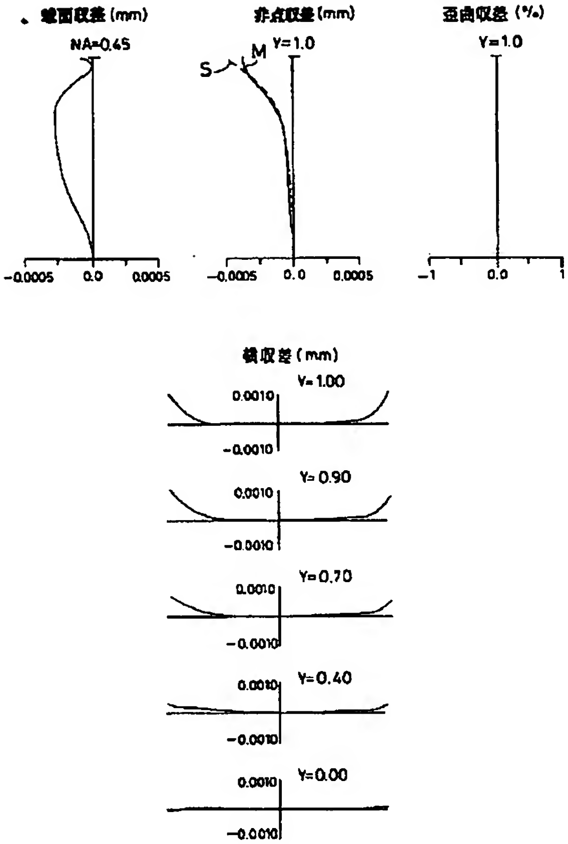
[Drawing 5]



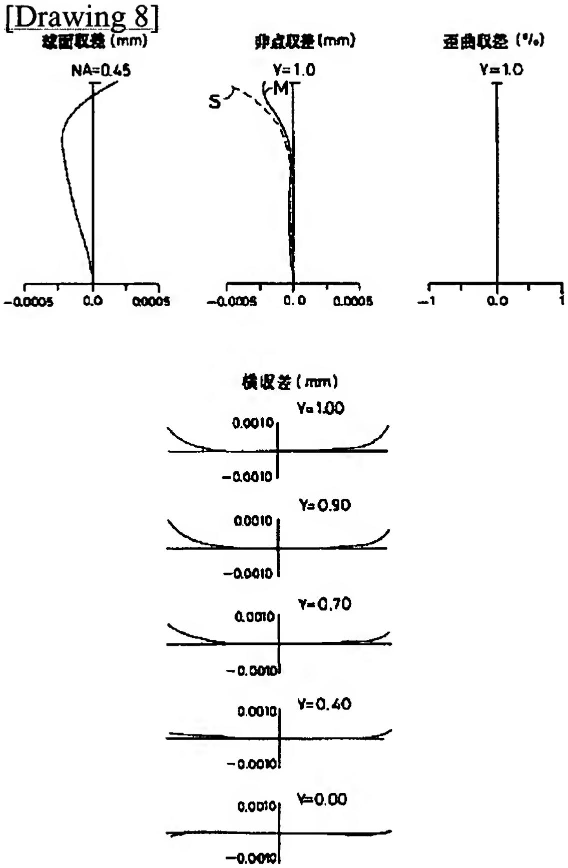
[Drawing 6]



[Drawing 7]



[Drawing 8]



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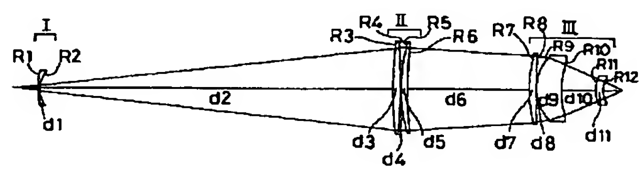
(54)【発明の名称】　縮小投影レンズ

(57)【要約】

【目的】　レンズ系の硝材総肉厚を薄くして透過率を向上させることができる高解像の縮小投影レンズ。

【構成】　負の屈折力を持つ第１群Ｉと、正の屈折力を持つ第２群IIと、正の屈折力を持つ第３群III との計３群から構成され、第１群Ｉ、第２群II、及び、全系の焦点距離をそれぞれ f_1、f_2、ｆとしたとき、$3<|f_1/f|<5$，$10<f_2/f<25$ の条件を満足する。各群に少なくとも１面の非球面を有し、各非球面は、レンズ光軸から周縁に行くに従って光軸近傍の屈折力を弱める形状の非球面であることが望ましく、また、各レンズを屈折率１．６以下の硝材により構成することが望ましい。



【特許請求の範囲】

【請求項１】　物体側より順に、負の屈折力を持つ第１レンズ群と、正の屈折力を持つ第２レンズ群と、正の屈折力を持つ第３レンズ群との計３群から構成され、第１レンズ群、第２レンズ群、及び、全系の焦点距離をそれぞれf_1、f_2、fとしたとき、以下の条件を満足することを特徴とする縮小投影レンズ。

$$3 < | f_1 / f | < 5 \quad \cdots (1)$$
$$10 < f_2 / f < 25 \quad \cdots (2)$$

【請求項２】　各群に少なくとも１面の非球面を有し、各非球面は、レンズ光軸から周縁に行くに従って光軸近傍の屈折力を弱める形状の非球面であることを特徴とする請求項１記載の縮小投影レンズ。

【請求項３】　各レンズを屈折率１．６以下の硝材により構成することを特徴とする請求項１記載の縮小投影レンズ。

【発明の詳細な説明】

【０００１】

【産業上の利用分野】本発明は、ＩＣ、ＬＳＩ等の集積回路を製造する装置に搭載される縮小投影レンズに関し、特に、縮小投影露光法によって回路パターンの描かれたマスクから、その回路パターンをシリコンウェハー上に転写する際に用いられる縮小投影レンズに関するものである。

【０００２】

【従来の技術】一般に、投影レンズによる投影像の解像力は、その開口数に比例し、使用する波長に反比例する。近年、回路パターンの高集積化が進み、それに伴って解像力の良いレンズが要求されてきており、開口数を大きくして行くとそれに比例して解像力は良くなって行くが、焦点深度が浅くなり、焦点合わせを非常に正確に行う必要が生じる。また、回路パターンを転写するシリコンウェハーの平坦度も非常に厳しい値が要求され、実用には向かなくなってしまう。そのため、近年では、開口数を大きくするよりも、使用波長を短くして焦点深度を保ちつつ解像度を上げることが行われるようになった。

【０００３】現在では、水銀灯による４３６ｎｍから３６５ｎｍの光が使用されるようになっているが、近年、２４８ｎｍを発光スペクトルとするＫｒＦエキシマレーザを使用する特開昭６０－１４０３１０号や、１９３ｎｍを発光スペクトルとするＡｒＦエキシマレーザを使用する特開平１－３１５７０９号等の提案がある。

【０００４】

【発明が解決しようとする課題】ところで、投影露光の使用波長が２５０ｎｍ以下になると、使用できる硝材の透過率の低下が少ないという観点から、硝材はSiO_2又はCaF_2に限られる。しかも、加工性等を考慮すると、SiO_2しか使用できる硝材はなく、さらに、波長２００ｎｍ以下では、このSiO_2を使用しても透過率が低い。従来のエキシマレーザを光源とし、SiO_2を使用した縮小投影レンズは、レンズ枚数が多く、硝材総肉厚が厚いので、透過率が低く、そのため、レンズの露光光熱吸収による倍率変動やベストフォーカス変動、露光量不足による低スループット等の問題があった。

【０００５】本発明はこのような状況に鑑みてなされたものであり、その目的は、レンズ系の硝材総肉厚を薄くして透過率を向上させることができる高解像の縮小投影レンズを提供することである。

【０００６】

【課題を解決するための手段】上記目的を達成するために、本発明の縮小投影レンズは、物体側より順に、負の屈折力を持つ第１レンズ群と、正の屈折力を持つ第２レンズ群と、正の屈折力を持つ第３レンズ群との計３群から構成され、第１レンズ群、第２レンズ群、及び、全系の焦点距離をそれぞれf_1、f_2、fとしたとき、以下の条件を満足することを特徴とするものである。

【０００７】

$$3 < | f_1 / f | < 5 \quad \cdots (1)$$
$$10 < f_2 / f < 25 \quad \cdots (2)$$

この場合、各群に少なくとも１面の非球面を有し、各非球面は、レンズ光軸から周縁に行くに従って光軸近傍の屈折力を弱める形状の非球面であることが望ましい。また、各レンズを屈折率１．６以下の硝材により構成することが望ましい。

【０００８】

【作用】以下、上記構成をとった理由とその作用を詳細に説明する。縮小投影レンズとしては、高解像度と広い露光領域を確保するために、像面湾曲をほぼ完全に補正しなくてはならない。像面湾曲を補正するには、ペッツバール和を小さく抑えればよいが、そのためには、正、負の屈折力を持つレンズを多数枚、適切な位置に配置することが必要である。そのために、縮小投影レンズはレンズ枚数が多くならざるを得ない。

【０００９】一方、縮小投影レンズの透過率を高くするためには、硝材総肉厚を薄くしなければならないが、そのためには、レンズ一枚一枚を薄くすると同時に、レンズ枚数を減らすことが必要である。つまり、高解像度を確保するという条件と硝材総肉厚を薄くするという条件を同時に満足するのは難しい。

【００１０】本発明の縮小投影レンズは、少ないレンズ枚数で効果的にペッツバール和を小さくするために、物体面に近く光線高の低い位置に配置した第１レンズ群の負の屈折力により、大きく負のペッツバール値を発生さ

せ、これ以降の像面側の光線高の高い位置に配置した第２レンズ群、第３レンズ群の正の屈折力により正のペッツバール和を小さくする構成をとっている。本構成をとることによって、少ないレンズ枚数でペッツバール和を小さくすることが可能となる。

【００１１】$|f_1/f|$とf_2/fについての条件式は、各レンズ群の屈折力を制限するものであり、高解像の投影レンズを達成するために必要な構成要件である。この場合、$|f_1/f|$が５以上であると、第１レンズ群の屈折力が小さくなりすぎ、全体のパッツバール和を小さく抑えられず、また、３以下であると、負の屈折力が大きくなることによって第１レンズ群の面の曲率がきつくなり、諸収差の発生が大きくなる。また、f_2/fが２５以上であると、少ない枚数の正の屈折力のレンズで光線を結像させることができず、また、１０以下であると、正の屈折力が大きくなることによって負の球面収差の発生が大きくなる。

【００１２】さらに、第３レンズ群の前側焦点位置をf_{3F}とし、第２レンズ群の後側主点を基準としたf_{3F}との距離をd_Sとしたとき、以下の条件を満足することが望ましい。

【００１３】

$$-0.1<d_S/f_2<0.2 \quad \cdots(3)$$

式（３）の符号は、第２レンズ群の後側主点よりもf_{3F}が像面側にあるときをプラス、物体側にあるときをマイナスとする。本発明のような縮小投影レンズにおいては、像面のディフォーカスや像面の平坦性の悪さによる像の倍率変動を抑えるために、射出側テレセントリックであることが一般的である。本発明の場合、f_{3F}は瞳位置に一致する。つまり、上記条件は第２レンズ群と瞳位置との関係を規定するものである。$-0.1>d_S/f_2$となると、第２レンズ群で内コマ収差が生じ、第１レンズ群で生ずる内コマ収差と相乗し、第３レンズ群でのコマ収差補正を困難にする。一方、$d_S/f_2>0.2$では、外コマ収差が強く発生し過ぎ、第３レンズ群の非球面は後述する通り、球面収差を補正すると共に外コマ収差を作り出す作用を持つが、第１レンズ群の発生する内コマ収差以上に、第２、第３レンズ群の外コマ収差が増え、全体として外コマ収差が残ってしまう。

【００１４】また、別に、本構成の縮小投影レンズは、各群に少なくとも１面の非球面を有することが望ましい。これは、少ないレンズ枚数の上記構成では補正しきれない諸収差を補正するためである。第１レンズ群の非球面は、ここで発生する正の歪曲収差を補正するために用いる。第２レンズ群の非球面は、構成レンズエレメントが少ないことによる負の球面収差を補正するために用いる。第３レンズ群の非球面は、第１レンズ群で発生した内コマ収差を補正するためと、本レンズ群自身で発生する球面収差を補正するために用いる。さらには、これらの非球面は、レンズ光軸から周縁に行くに従って光軸近傍の屈折力を弱める形状の非球面であることが好ましい。

【００１５】また、別に、本構成の縮小投影レンズは、屈折率１．６以下の硝材で構成することが好ましい。これは、エキシマレーザのようなスペクトル幅が非常に狭い光を使用するに当たり、レンズの色収差を考慮しなくてもよく、色収差補正のために屈折率が１．６以上の硝材を使用する必要がないからである。

【００１６】

【実施例】以下、本発明の縮小投影レンズの実施例１～４について説明する。図１～図４にそれぞれ実施例１～４のレンズ断面図を示すが、何れの実施例においても、倍率は１／５、開口数は０．４５、物像間距離は１０００mm、露光領域は１０×１０mmであり、硝材は全てSiO_2からなる。なお、これらの実施例のレンズデータは後記する。

【００１７】まず、本発明の実施例１について説明する。図１において、第１群Ｉは物体側に凸面を向けた負のメニスカスレンズ１枚から、第２群IIは両凸レンズ１枚と物体側に凸面を向けた正のメニスカスレンズ１枚の計２枚から、第３群III は像側に凹面を向けた正のメニスカスレンズ２枚と像側に凹面を向けたパワーレスのメニスカスレンズ１枚の計３枚からなる。

【００１８】この実施例１と次に述べる実施例２は、特に、第３群III の最も像面に近いところに像側に凹面を向けたパワーレスのメニスカスレンズ１枚を配置しているが、この場合、高次のコマ収差を補正するために、少なくともその１面に非球面を用いるのがさらに好ましい。さらに、このパワーレスのメニスカスレンズの焦点距離をf_{33}としたとき、以下の条件を満足することが好ましい。

$$2000\ (\mathrm{mm})<|f_{33}| \quad \cdots(4)$$

$|f_{33}|$が２０００mm以下であると、球面成分で低次のコマ収差が発生してしまう。

【００１９】次に、本発明の実施例２について説明する。図２において、第１群Ｉは物体側に凸面を向けた負のメニスカスレンズ１枚から、第２群IIは物体側に凸面を向けた正のメニスカスレンズ１枚から、第３群III は両凸レンズ１枚と像側に凹面を向けた正のメニスカスレンズ１枚と像側に凹面を向けたパワーレスのメニスカスレンズ１枚の計３枚からなる。第３群III の像側に凹面を向けたパワーレスのメニスカスレンズについては、実施例１と同様の作用を持つ。

【００２０】次に、本発明の実施例３については、図３において、第１群Ｉは物体側に凸面を向けた負のメニスカスレンズ１枚から、第２群IIは物体側に凸面を向けた正のメニスカスレンズ１枚から、第３群III は両凸レンズ１枚と像側に凹面を向けた正のメニスカスレンズ１枚

からなる。

【００２１】本発明の実施例４については、図４において、第１群Ｉは物体側に凸面を向けた負のメニスカスレンズ１枚から、第２群IIは物体側に凸面を向けた正のメニスカスレンズ１枚から、第３群III は両凸レンズ１枚と像側に凹面を向けた正のメニスカスレンズ１枚からなる。

【００２２】以下に各実施例のレンズデータを示すが、レンズデータ中、R_1、R_2、・・・は各レンズ面の曲率半径、d_1、d_2・・・は各レンズ面間の間隔、n_1、n_2、・・・は各レンズの１９３ｎｍでの屈折率であり、また、非球面形状は光軸方向をｘ、光軸に直交する方向をｙとしたとき、次式で表される。

$$x=(y^2/r)/[1+\{1-(y^2/r^2)\}^{1/2}]+Ay^4+By^6+Cy^8+Dy^{10}$$

ただし、ｒは近軸曲率半径、Ａ、Ｂ、Ｃ、Ｄはそれぞれ４次、６次、８次、１０次の非球面係数である。

【００２３】実施例１

R_1 = 149.072	d_1 = 4	n_1 =1.56
R_2 = 53.071（非球面）	d_2 = 580.412	
R_3 = 685.808	d_3 = 12.808	n_2 =1.56
R_4 = -855.88	d_4 = 0.08	
R_5 = 332.732	d_5 = 10.304	n_3 =1.56
R_6 = 970.134（非球面）	d_6 = 196.429	
R_7 = 236.31	d_7 = 10.938	n_4 =1.56
R_8 = 1175.523	d_8 = 0.714	
R_9 = 87.26	d_9 = 42.891	n_5 =1.56
R_{10}= 194.005	d_{10}= 53.429	
R_{11}= 68.841（非球面）	d_{11}= 13.136	n_6 =1.56
R_{12}= 59.862		

非球面係数

第２面

$A=-0.105\times10^{-5}$　　$B=-0.126\times10^{-9}$

$C=-0.242\times10^{-13}$　　$D=-0.176\times10^{-16}$

第６面

$A=0.986\times10^{-8}$　　$B=0.485\times10^{-13}$

$C=0.116\times10^{-17}$　　$D=0.44\times10^{-22}$

第１１面

$A=-0.745\times10^{-6}$　　$B=-0.359\times10^{-9}$

$C=-0.115\times10^{-12}$　　$D=-0.595\times10^{-17}$

。

【００２４】実施例２

R_1 = 1736.215	d_1 = 5.866	n_1 =1.56
R_2 = 68.889（非球面）	d_2 = 543.701	
R_3 = 263.312	d_3 = 11.509	n_2 =1.56
R_4 = 819.653（非球面）	d_4 = 165.728	
R_5 = 220.315	d_5 = 22.409	n_3 =1.56
R_6 = -1415.823	d_6 = 49.904	
R_7 = 106.825	d_7 = 37.488	n_4 =1.56
R_8 = 254.313	d_8 = 46.233	
R_9 = 96.597（非球面）	d_9 = 6.904	n_5 =1.56
R_{10}= 103.38		

非球面係数

第２面

$A=-0.639\times10^{-6}$　　$B=-0.155\times10^{-10}$

$C=-0.103\times10^{-13}$　　$D=0.563\times10^{-18}$

第４面

$A=0.223\times10^{-7}$　　$B=0.151\times10^{-12}$

$C=0.241\times10^{-17}$　　$D=0.209\times10^{-21}$

第９面

$A=-0.277\times10^{-6}$　　$B=-0.522\times10^{-10}$

$C=-0.497\times10^{-14}$　　$D=0.69\times10^{-18}$

。

【００２５】実施例３

R_1 = 6336.701	d_1 = 4	n_1 =1.56
R_2 = 65.016（非球面）	d_2 = 561.539	
R_3 = 261.005	d_3 = 15.817	n_2 =1.56
R_4 = ∞（非球面）	d_4 = 176.959	
R_5 = 232.483	d_5 = 20.768	n_3 =1.56
R_6 = -632.184	d_6 = 40.867	
R_7 = 126.144	d_7 = 28.872	n_4 =1.56

$R_8 =$ 413.522（非球面）

非球面係数

第2面

$A = -0.779\times10^{-6}$　$B = -0.179\times10^{-10}$

$C = -0.182\times10^{-13}$　$D = 0.307\times10^{-17}$

第4面

$A = 0.268\times10^{-7}$　$B = 0.792\times10^{-13}$

$C = 0.250\times10^{-17}$　$D = 0.155\times10^{-21}$

第8面

$A = 0.438\times10^{-7}$　$B = 0.215\times10^{-12}$

$C = 0.424\times10^{-16}$　$D = 0.645\times10^{-20}$

【0026】実施例4

$R_1 =$ 7761.76	$d_1 =$ 4	$n_1 = 1.56$
$R_2 =$ 65.426（非球面）	$d_2 =$ 566.358	
$R_3 =$ 260.181	$d_3 =$ 14.689	$n_2 = 1.56$
$R_4 =$ 3358.89（非球面）	$d_4 =$ 167.605	
$R_5 =$ 217.213	$d_5 =$ 21.986	$n_3 = 1.56$
$R_6 =$ −768.035（非球面）	$d_6 =$ 44.28	
$R_7 =$ 137.413	$d_7 =$ 26.994	$n_4 = 1.56$
$R_8 =$ 634.5（非球面）		

非球面係数

第2面

$A = -0.777\times10^{-6}$　$B = -0.144\times10^{-10}$

$C = -0.182\times10^{-13}$　$D = 0.307\times10^{-17}$

第4面

$A = 0.275\times10^{-7}$　$B = 0.13\times10^{-12}$

$C = 0.417\times10^{-17}$　$D = 0.175\times10^{-21}$

第6面

$A = 0.523\times10^{-9}$　$B = -0.25\times10^{-12}$

$C = 0.951\times10^{-17}$　$D = -0.425\times10^{-22}$

第8面

$A = 0.484\times10^{-7}$　$B = 0.678\times10^{-12}$

$C = 0.114\times10^{-16}$　$D = 0.534\times10^{-20}$

【0027】次に、上記実施例1～4の球面収差、非点収差、歪曲収差、横収差を表す収差図をそれぞれ図5～図8に示す。図中、Yは像高比、Mはメリジオナル像面、Sはサジタル像面を示す。また、各実施例の条件式（1）～（3）の値を次表に示す。

	$\mid f_1 / f \mid$	f_2 / f	d_s / f_2
実施例1	4.48	11.63	+0.15
実施例2	4.1	21.99	+0.14
実施例3	3.95	15.64	−0.04
実施例4	4.01	17.09	−0.05

【0028】

【発明の効果】以上説明したように、本発明によれば、レンズ系の硝材総肉厚が薄く、透過率の良い、高解像の縮小投影レンズを得ることができる。

【図面の簡単な説明】

【図1】本発明の縮小投影レンズの実施例1のレンズ断面図である。

【図2】実施例2のレンズ断面図である。

【図3】実施例3のレンズ断面図である。

【図4】実施例4のレンズ断面図である。

【図5】実施例1の球面収差、非点収差、歪曲収差、横収差を表す収差図である。

【図6】実施例2の球面収差、非点収差、歪曲収差、横収差を表す収差図である。

【図7】実施例3の球面収差、非点収差、歪曲収差、横収差を表す収差図である。

【図8】実施例4の球面収差、非点収差、歪曲収差、横収差を表す収差図である。

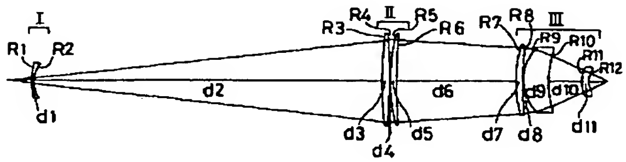
【符号の説明】

I　…第1レンズ群

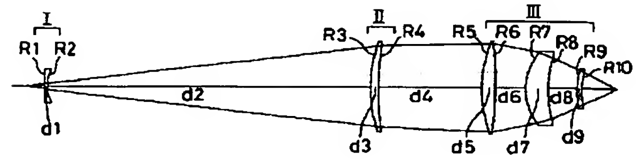
II　…第2レンズ群

III　…第3レンズ群

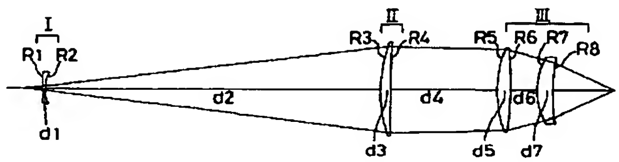
【図1】



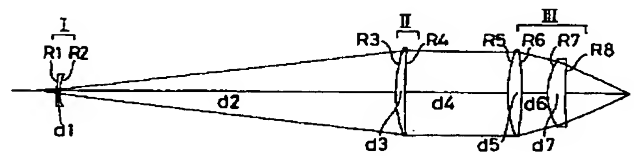
【図2】



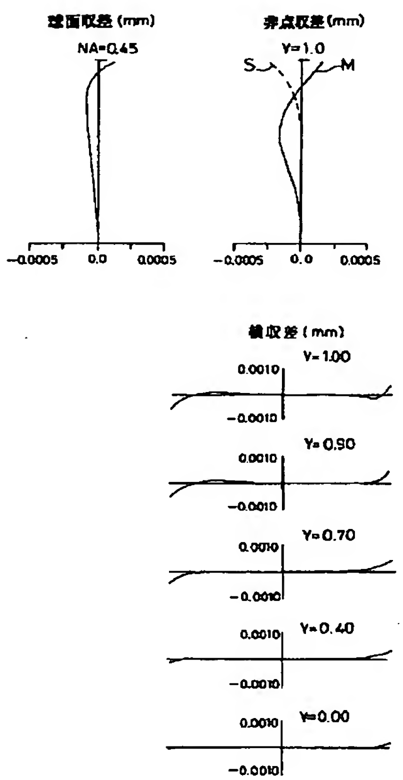
【図3】



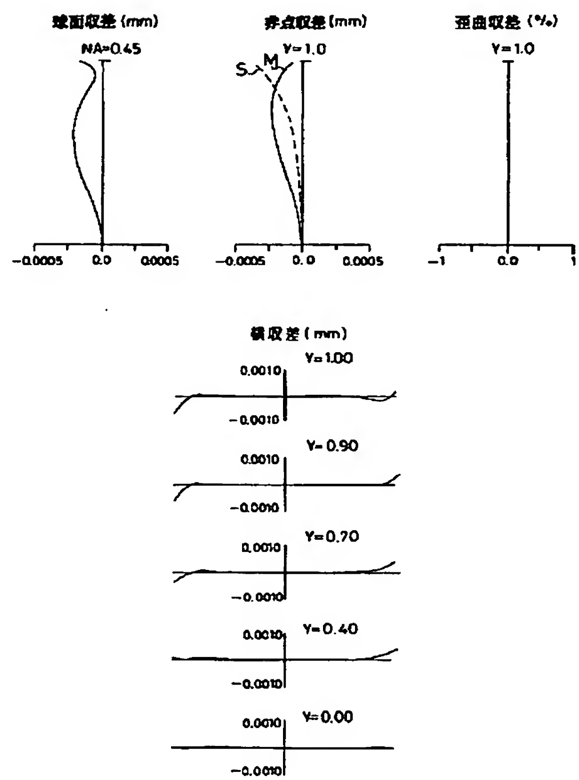
【図4】



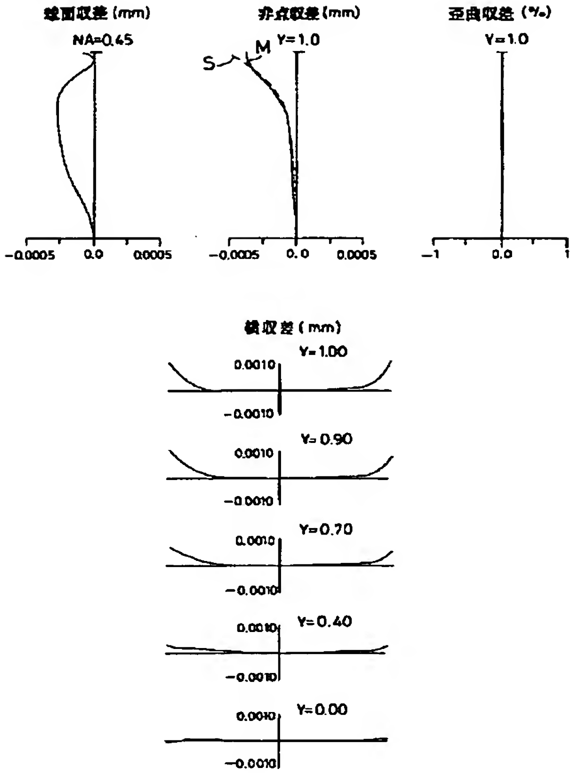
【図5】



【図6】

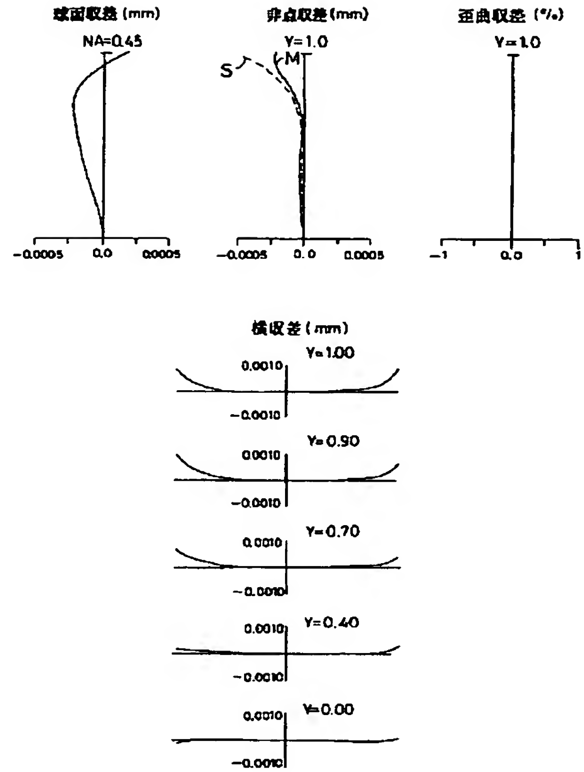


【図７】



球面収差 (mm)
NA=0.45
非点収差 (mm)
Y=1.0
S
M
歪曲収差 (%)
Y=1.0
-0.0005
0.0
0.0005
-1
1
横収差 (mm)
Y=1.00
Y=0.90
Y=0.70
Y=0.40
Y=0.00
0.0010
-0.0010

【図８】



球面収差 (mm)
NA=0.45
非点収差 (mm)
Y=1.0
S
M
歪曲収差 (%)
Y=1.0
-0.0005
0.0
0.0005
-1
1
横収差 (mm)
Y=1.00
Y=0.90
Y=0.70
Y=0.40
Y=0.00
0.0010
-0.0010